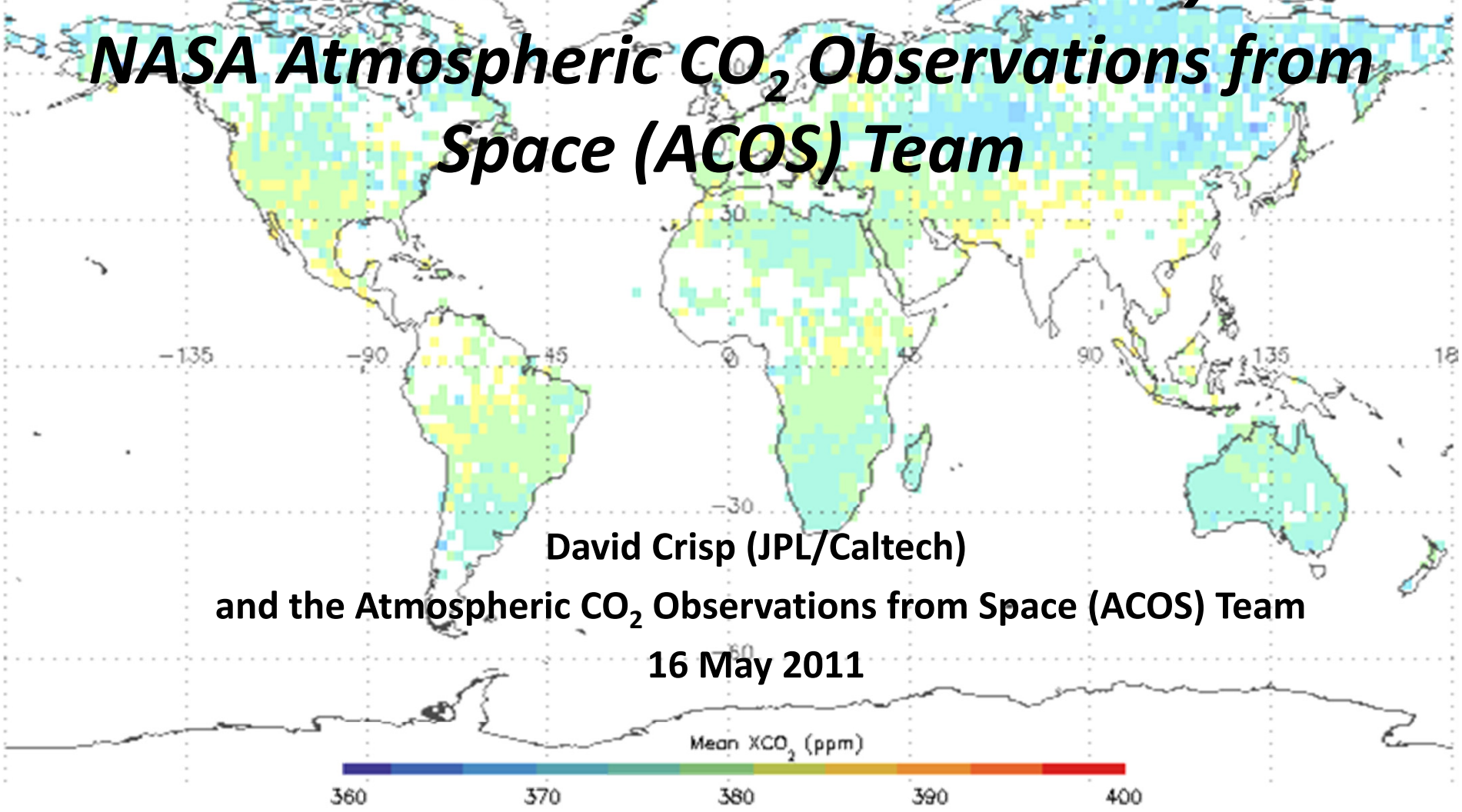
Contributions to GOSAT Missions by the NASA Atmospheric CO_2 Observations from Space (ACOS) Team



David Crisp (JPL/Caltech)

and the Atmospheric CO_2 Observations from Space (ACOS) Team

16 May 2011

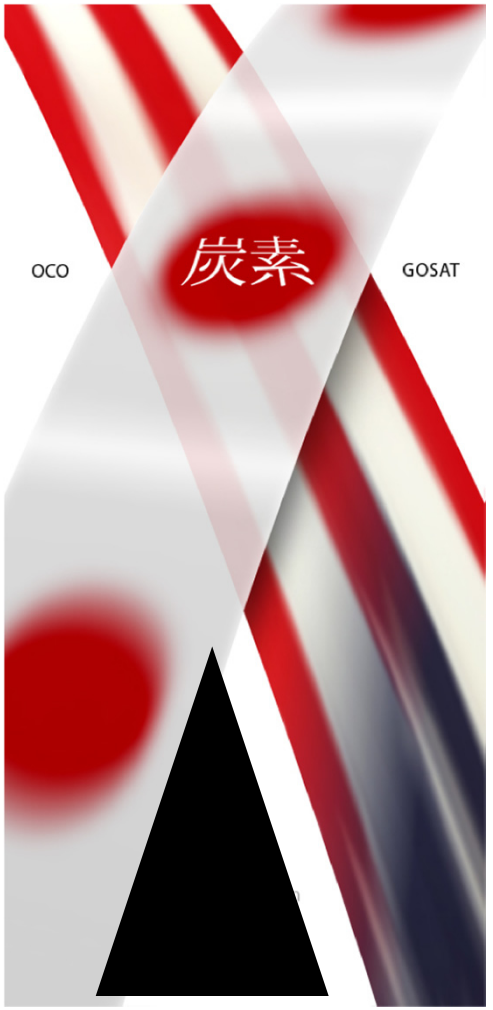
OCO and GOSAT Collaboration

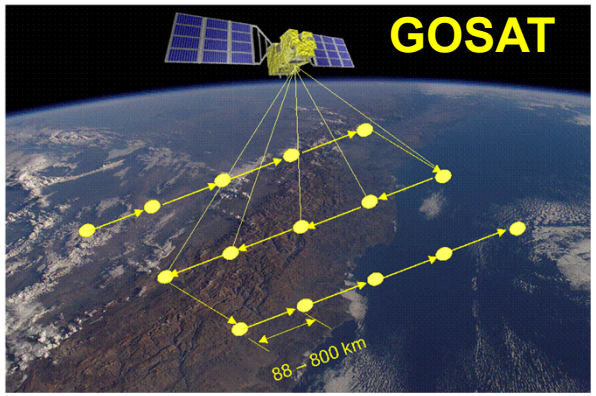
The OCO and GOSAT teams formed a close partnership during the implementation phases of these 2missions to:

- Cross calibrate the OCO instrument and TANSO-FTS
- Cross validate OCO and GOSAT X_{CO2} retrievals against a common standard

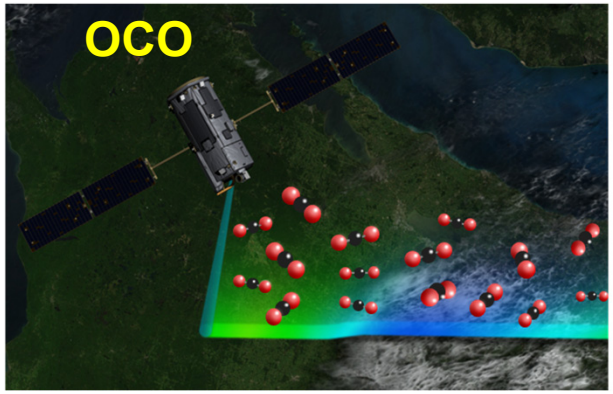
The primary objectives of this partnership were to:

- Accelerate understanding of this new data source
- Facilitate combining results from GOSAT and OCO to improve spatial and temporal coverage





3-day ground track repeat cycle resolves weather



Continuous high resolution measurements along track

The Launch of GOSAT and Loss of OCO

GOSAT launched successfully on 23 January 2009

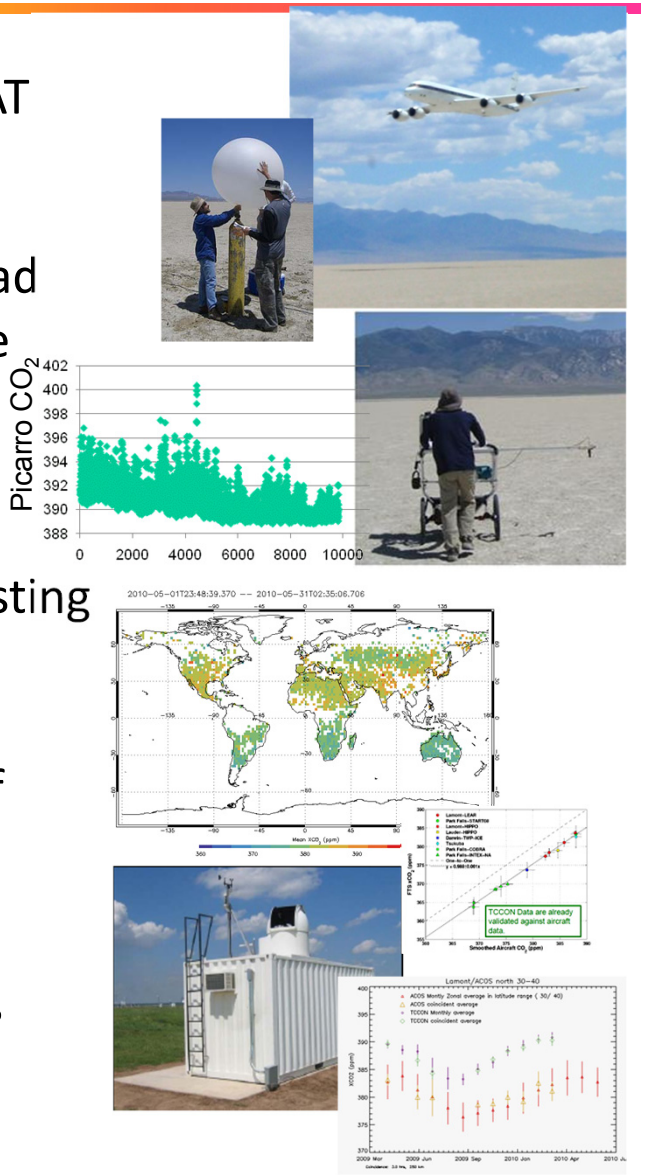
OCO was lost a month later when its launch system failed

Working with the GOSAT Team

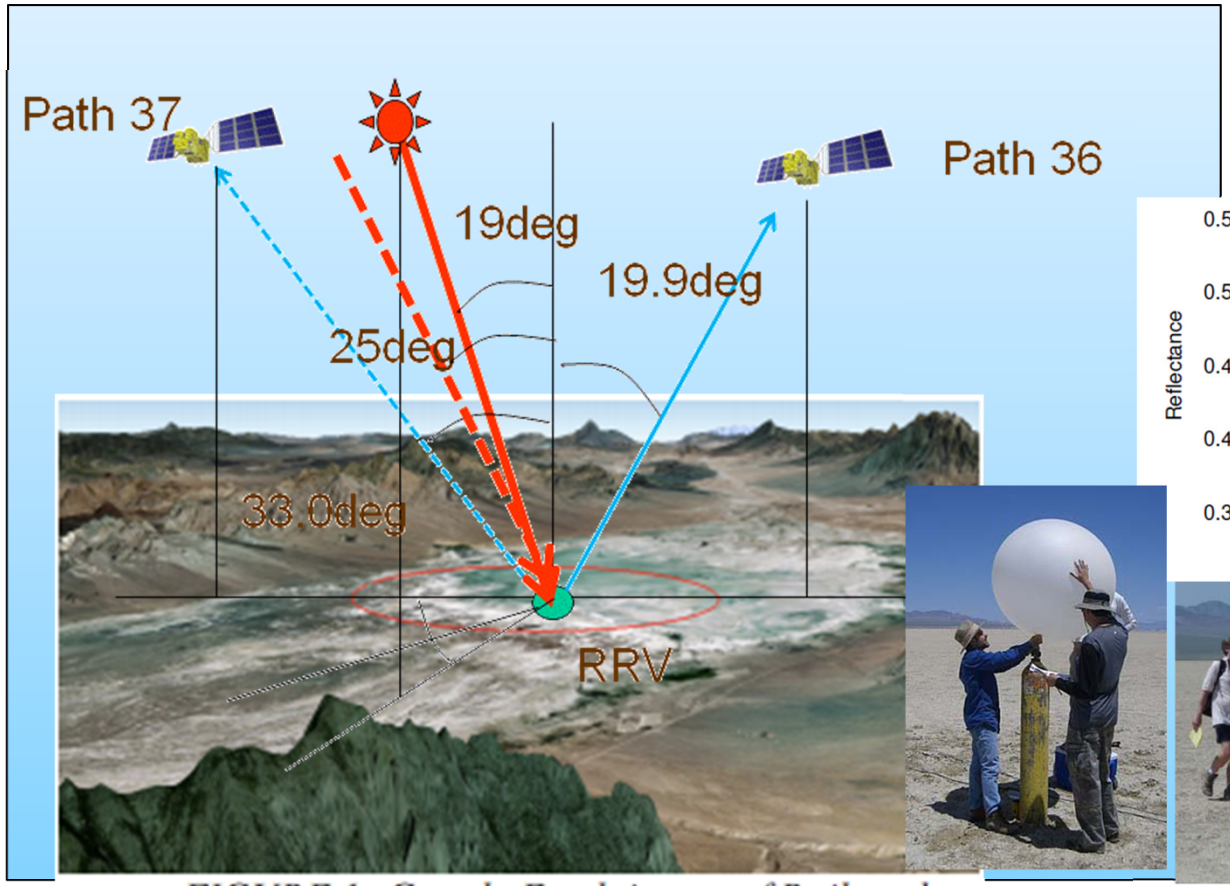
- Immediately after the loss of the OCO Mission, the GOSAT Project manager invited the OCO Team to participate in the GOSAT data analysis
- NASA reformulated the OCO team as the "Atmospheric CO_2 Observations from Space" (ACOS) team
- This collaboration benefits the GOSAT team by:
  - Combining the ground based calibration and validation resources of both teams to maximize the accuracy of the GOSAT data
  - Combining the scientific expertise from both teams to accelerate our understanding of this new, space-based data source
- This collaboration benefits the NASA OCO by
  - Providing direct experience with the analysis of space based CO_2 measurements
  - Accelerating the delivery of precise CO_2 measurements from future NASA carbon dioxide monitoring missions

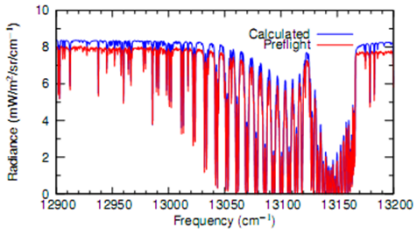
Elements of the ACOS/GOSAT Collaboration

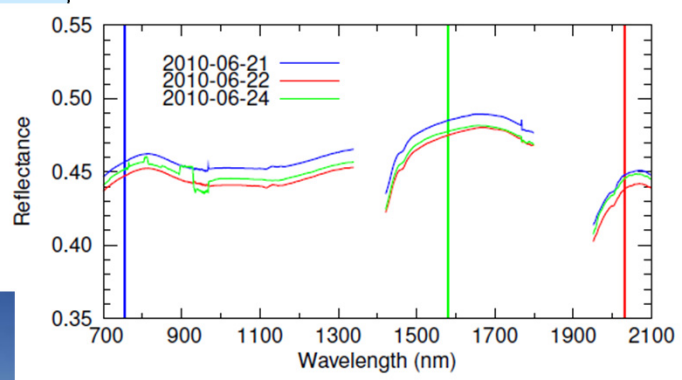
- The ACOS team is collaborating closely with the GOSAT teams at JAXA and NIES to:
  - Conduct vicarious calibration campaigns in Railroad Valley, Nevada, U.S.A. and analyze results of those campaigns
  - Retrieve X_{CO2} from GOSAT spectra
    - Model development, implementation, and testing
    - Data production and delivery
  - Validate GOSAT retrievals through comparisons of
    - GOSAT retrievals with TCCON measurements
    - 0ther validation standards (surface pressure, aircraft and ground-based CO_2 measurements



Vicarious Calibration in Railroad Valley, NV

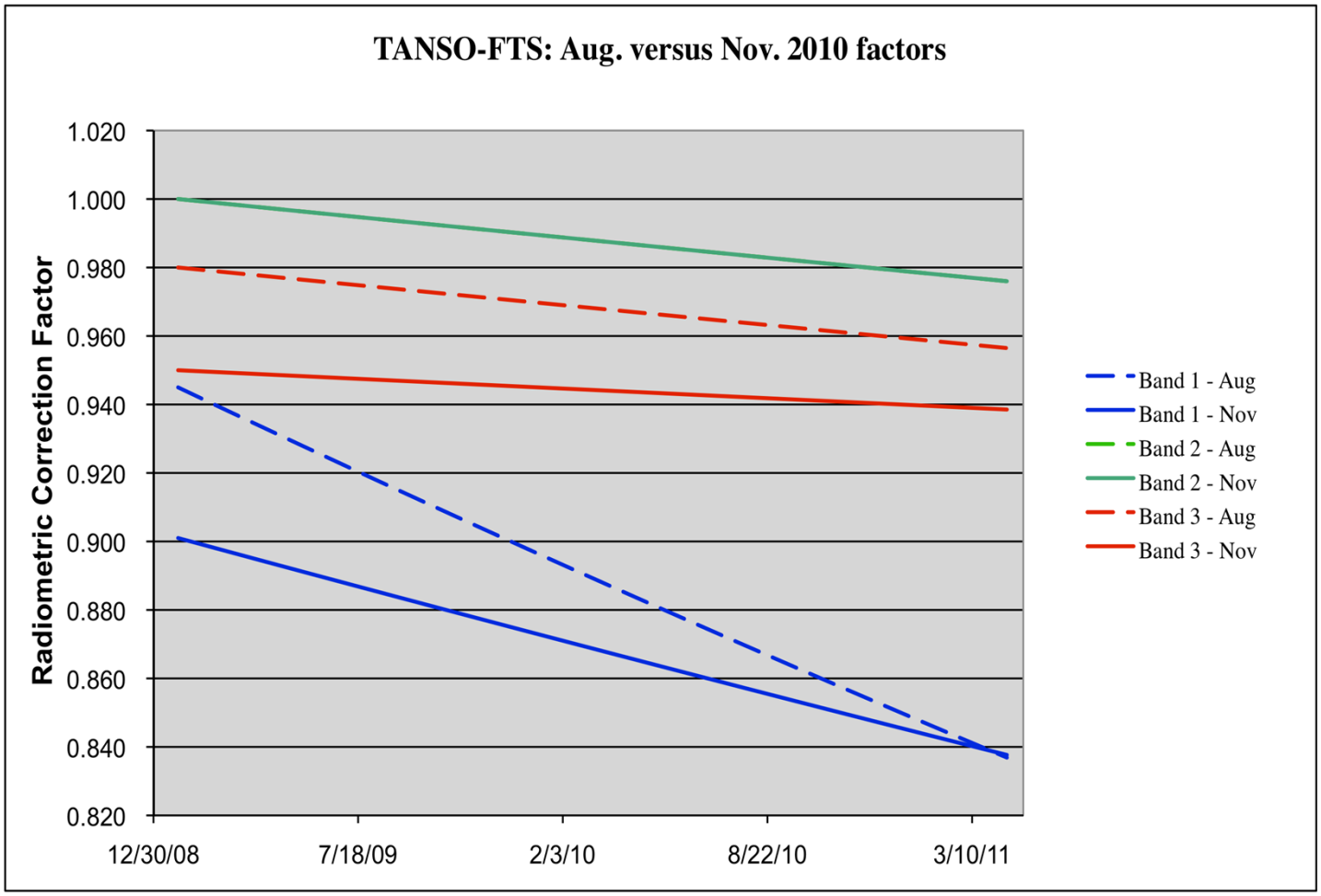






The NASA and GOSAT teams are collaborating to collect ground based and aircraft measurements over Railroad Valley, Nevada during GOSAT overflights to monitor the calibration of the GOSAT instruments

TANSO-FTS Throughput Degradation with time



For both the A-band (FTS-B1) and the SCO2 band (FTS-B3), the August coefficients produced a smaller initial correction factor but a higher rate of degradation than the November values. The WCO2 band (Band 2, in GOSAT terms) correction factors have not changed.

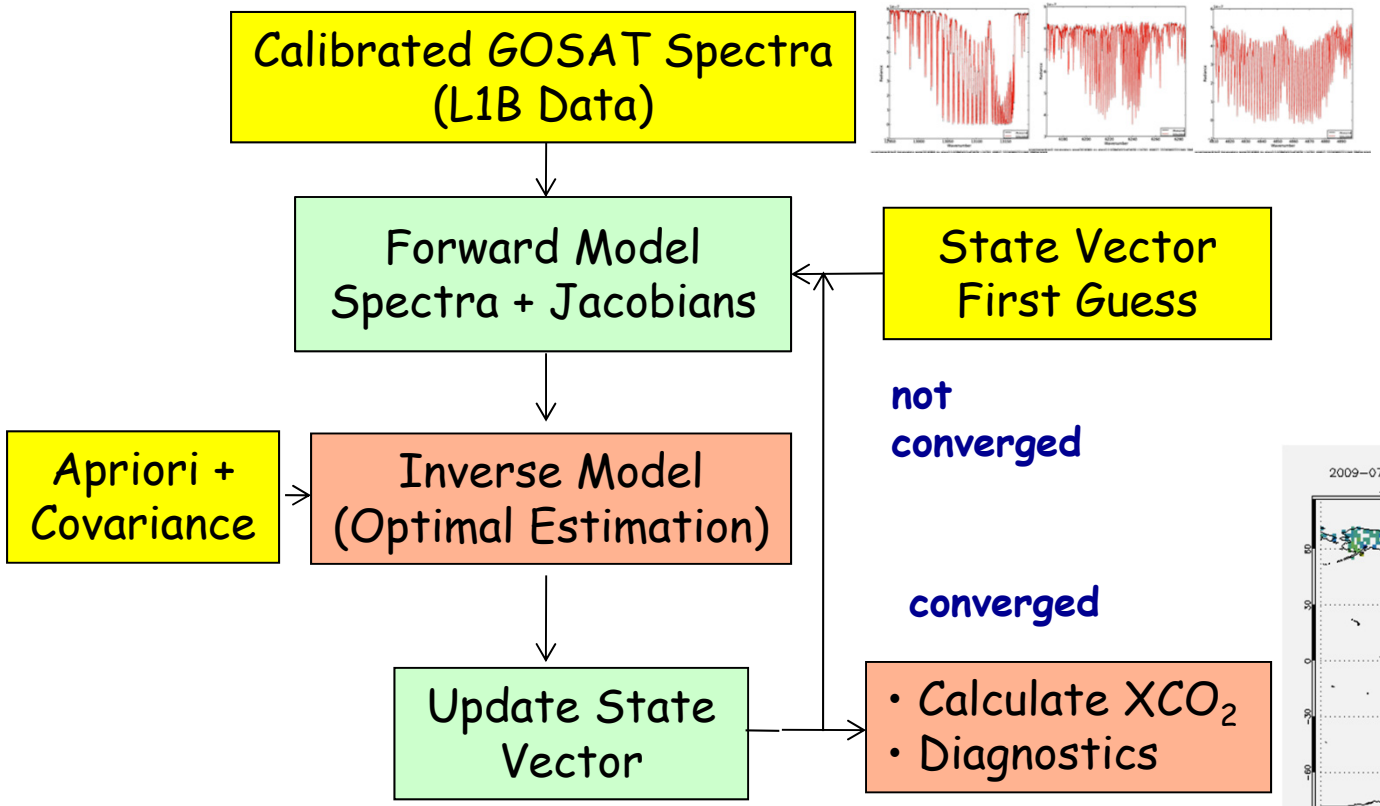
Aug2010 (dashed) and Nov2010 (solid) radiometric correction factors.

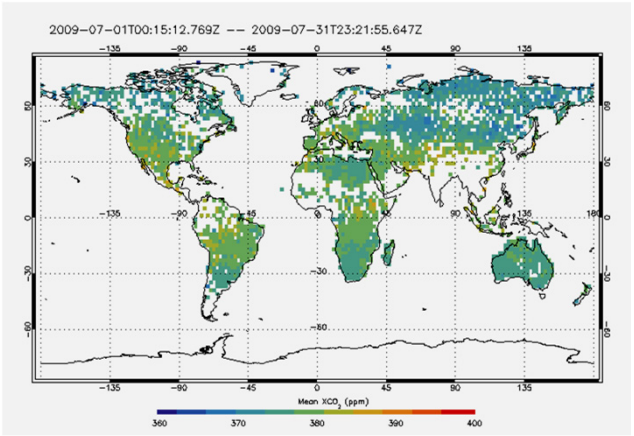
Retrieving X_{CO2} from GOSAT Data

The OCO Retrieval Algorithm was modified to retrieve X_{CO2} from GOSAT measurements

- "Full-physics" forward model
- Inverse model based on optimal estimation

State Vector
CO_2 profile (full)
H_2O profile (scale factor)
Temperature profile (offset)
Aerosol Profiles
Surface Pressure
Albedo (Mean, Slope)
Wavelength Shift (+ stretch)

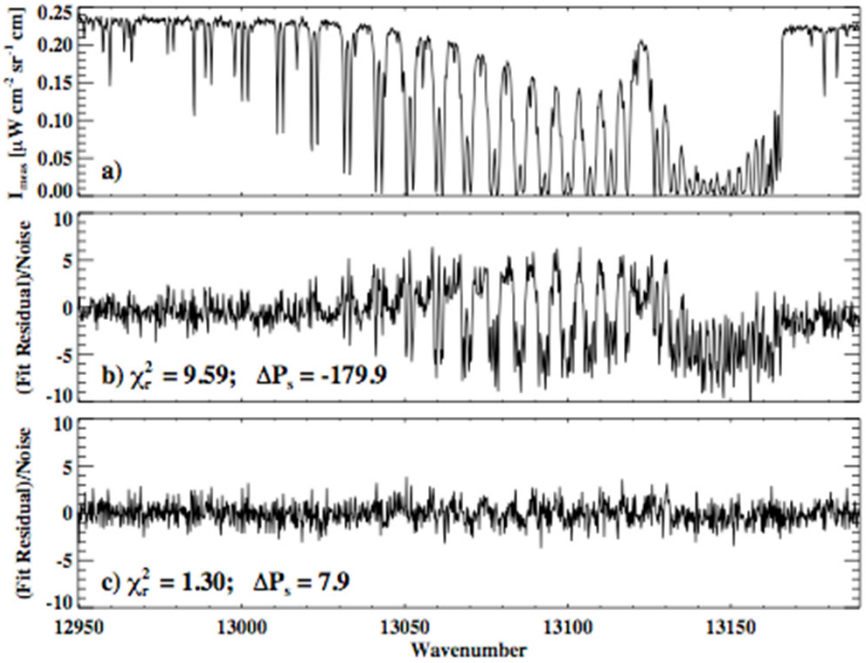




See poster by O'Dell et al. in Poster Session 3

Pre-Screening: The ACOS Cloud Screen

- A Spectroscopic cloud screening algorithm based on the O_2 A-band is currently being used for GOSAT retrievals
  - Fits a clear sky atmosphere to every sounding in the O_2 A band.
  - High values of χ^2 and large differences between the retrieved surface pressure and the ECMWF prior indicate the presence of clouds
  - Over non-glint ocean, a simple albedo test is also used.



Example A-Band fit

Poor fit (χ^2 = 9.6) indicates presence of cloud

Small residuals and good agreement between retrieved and ECMWF surface pressure indicates cloud free

See poster by Taylor et. al. in Poster Session 2

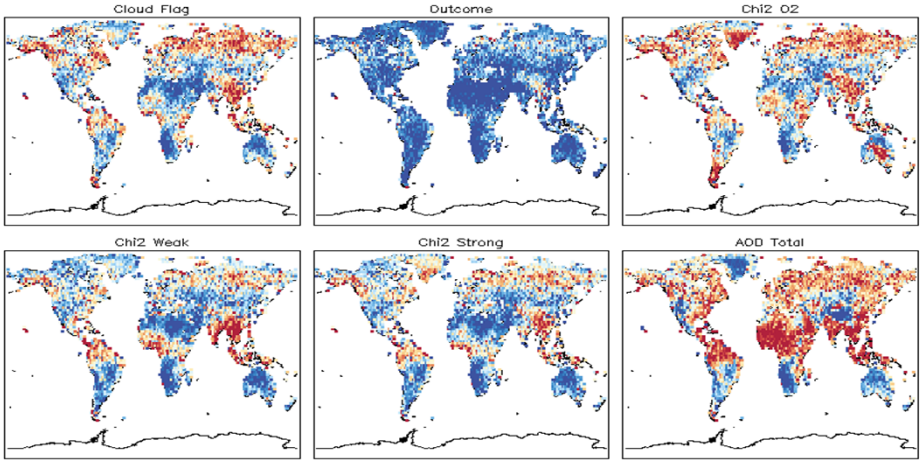
Post Screening Improves Accuracy

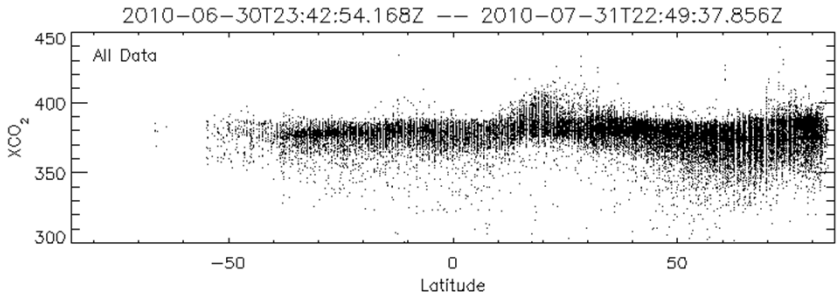
Errors can be further reduced by post-screening retrievals, based on a series of criteria, including:

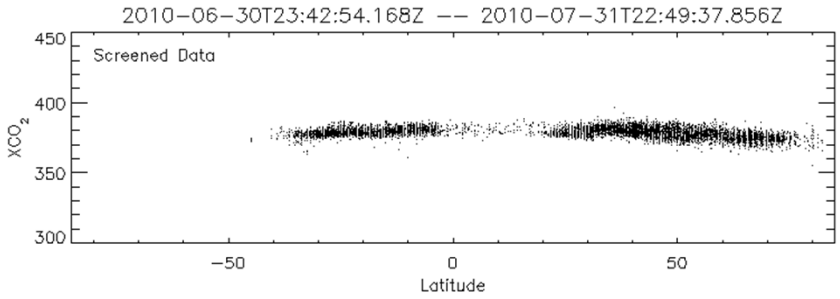
- Measurement SNR
- Convergence
- Goodness of spectral fit
- Surface pressure error
- Evidence for clouds or optically thick aerosols
- A postiori retrieval error
- Evidence of known biases

The cloud screen is responsible for the largest data reductions.

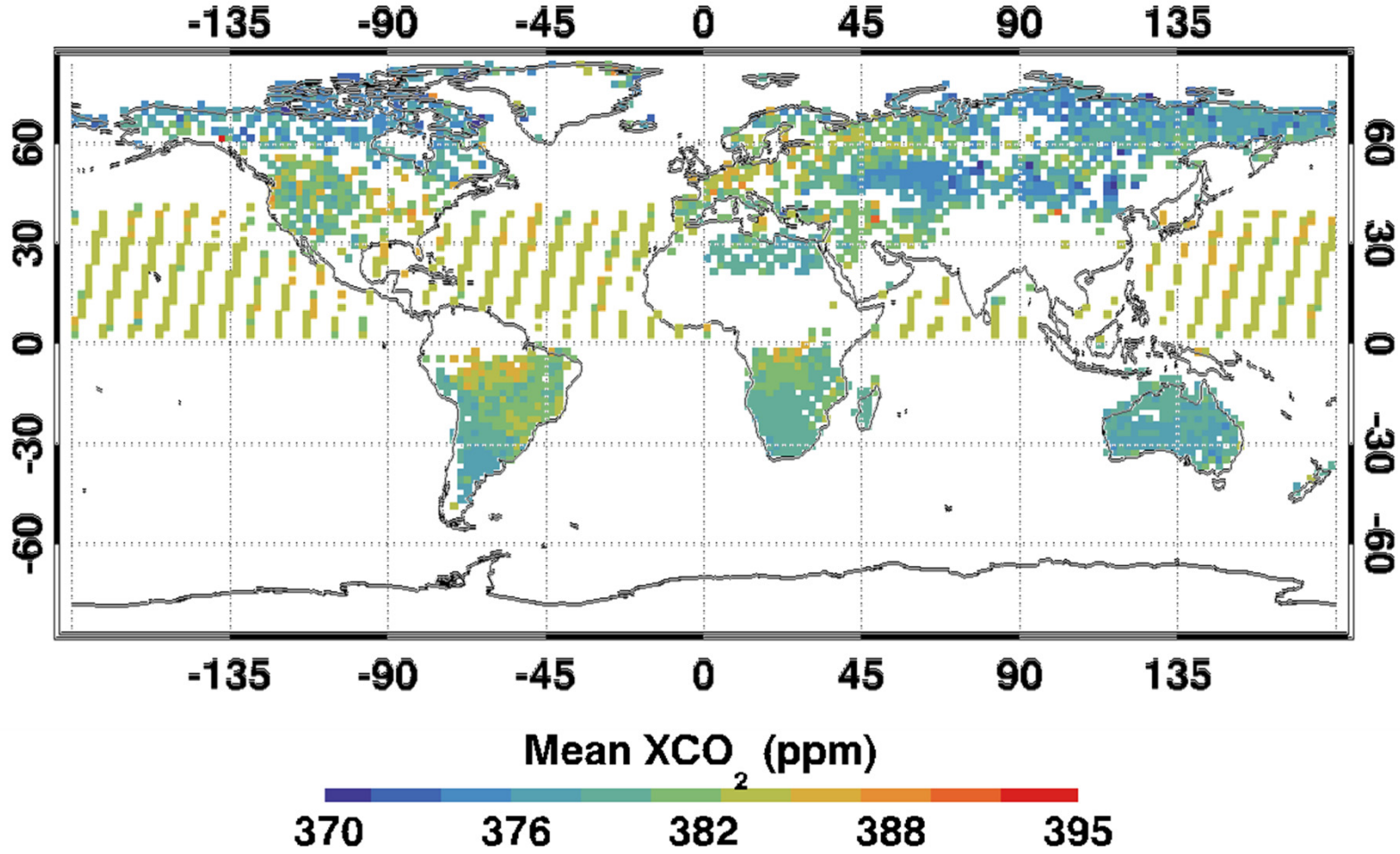
- Improved cloud screening algorithms are a major focus of our development effort



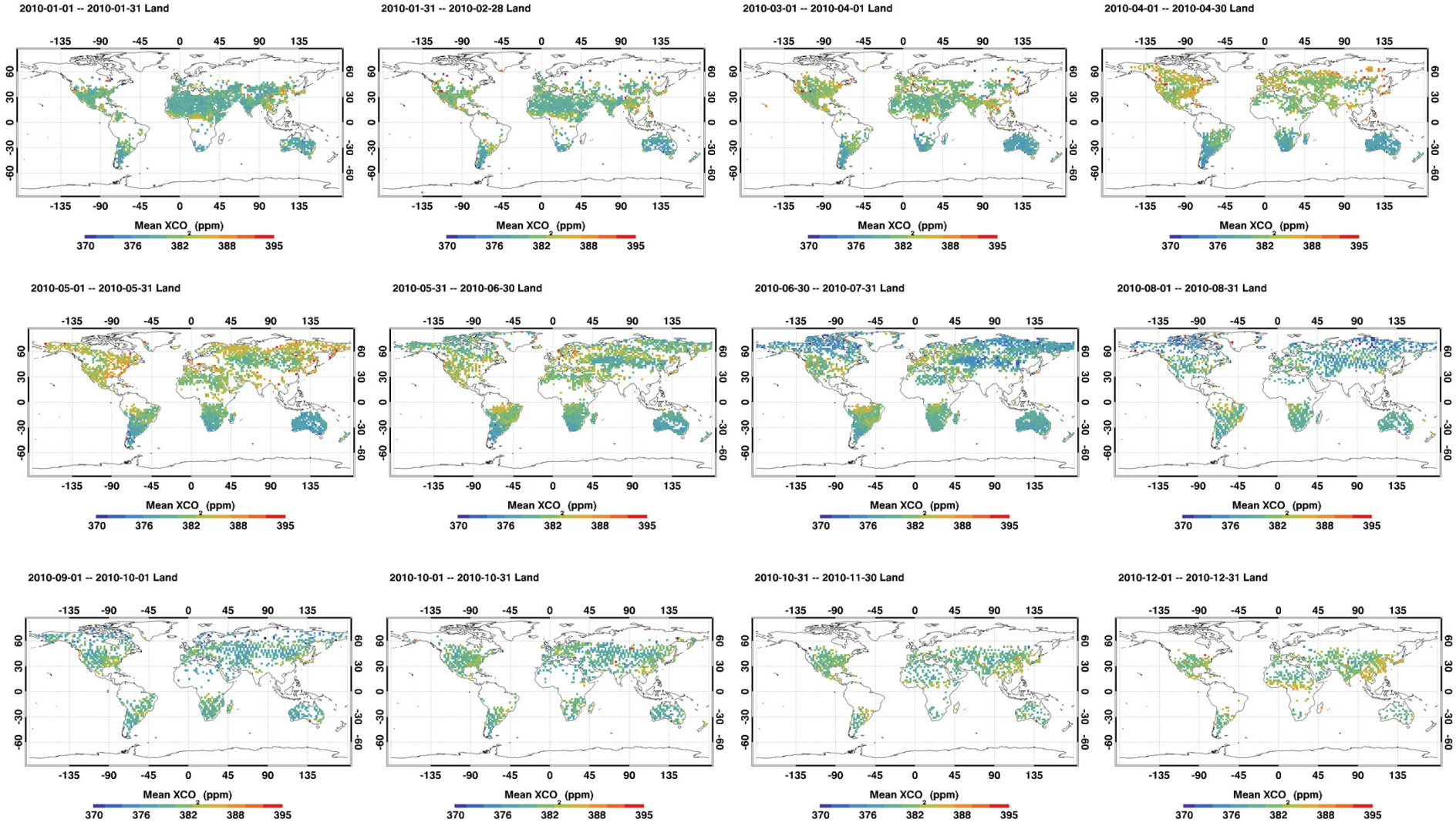




GOSAT XCO2 Retrievals for July 2010



A Year of ACOS/GOSAT X_{CO2}



ACOS GOSAT Data Release

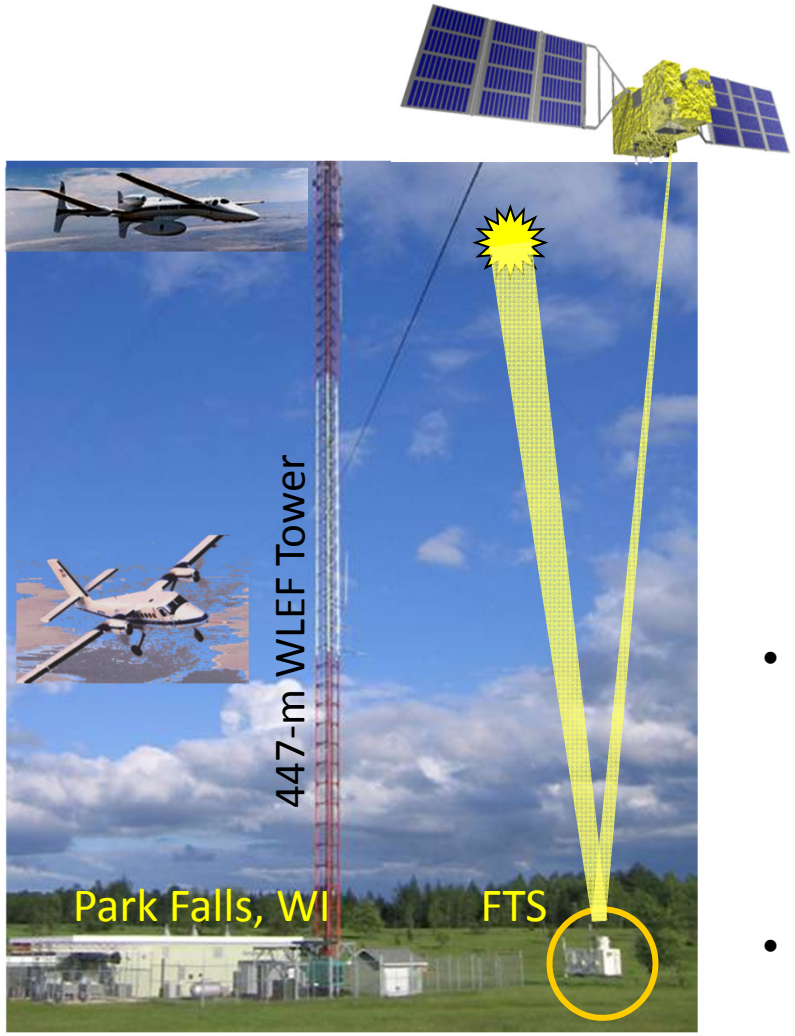
- The ACOS L2 Standard Products are now being distributed on the GSFC Mirador site.

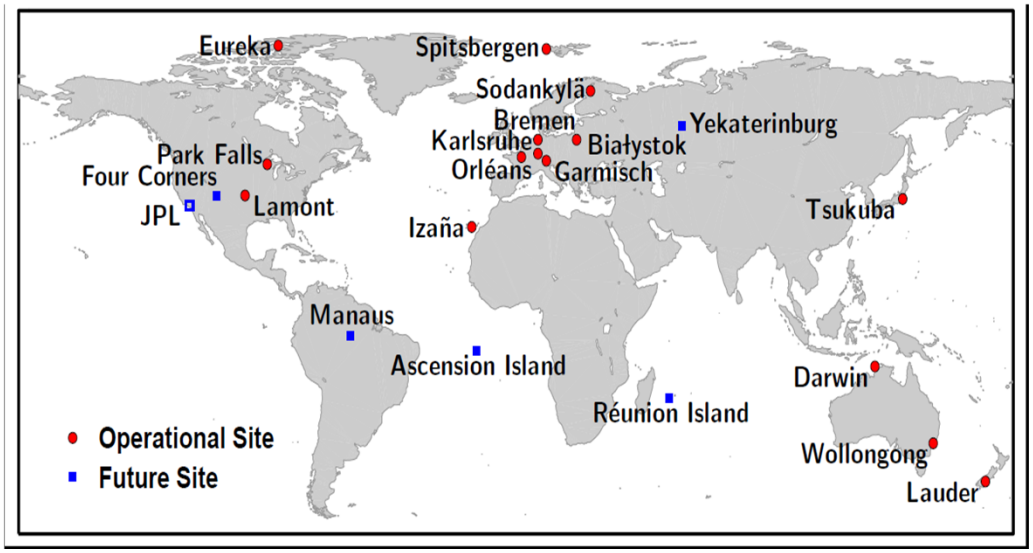
http://mirador.gsfc.nasa.gov/

- You can find the data, along with a README and a Data Quality Statement at the site:

http://disc.sci.gsfc.nasa.gov/acdisc/documentation/ACOS.shtml

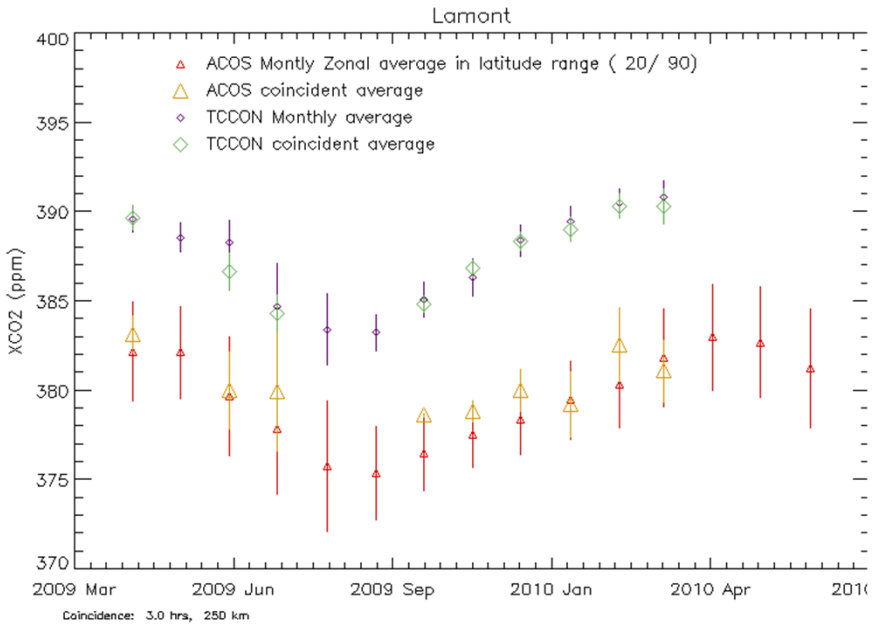
Validation of GOSAT Products

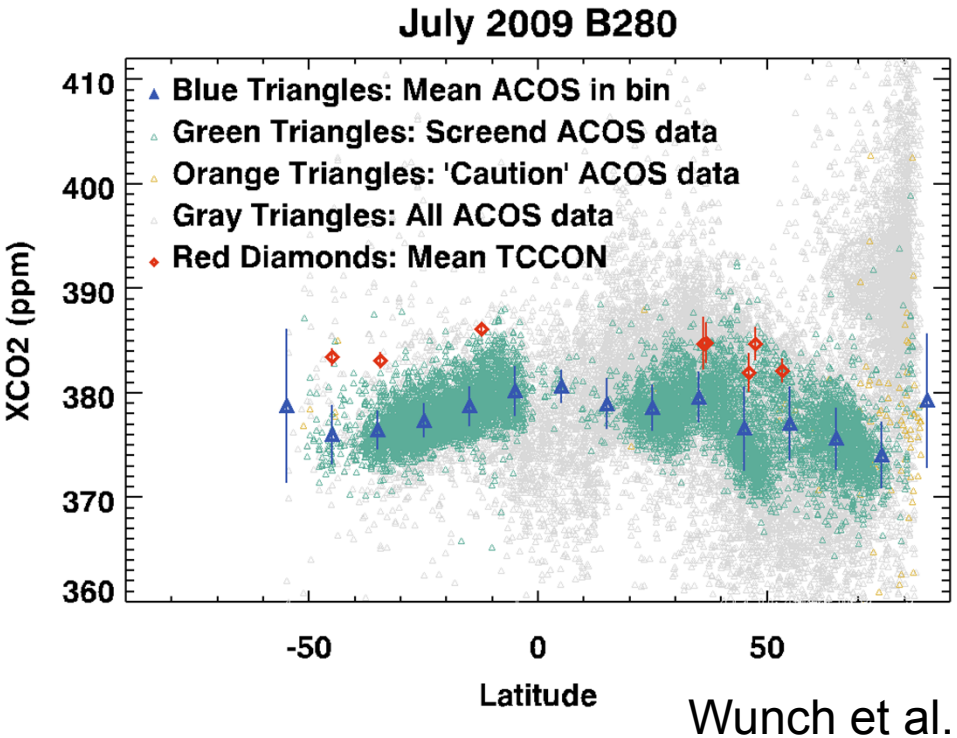




- GOSAT X_{CO2} retrievals are being compared with those from the ground based Total Carbon Column Observing Network to validate their accuracy
- GOSAT surface pressure retrievals are being compared to estimates from ECMWF to validate the dry air mole fraction

Comparisons of GOSAT and TCCON



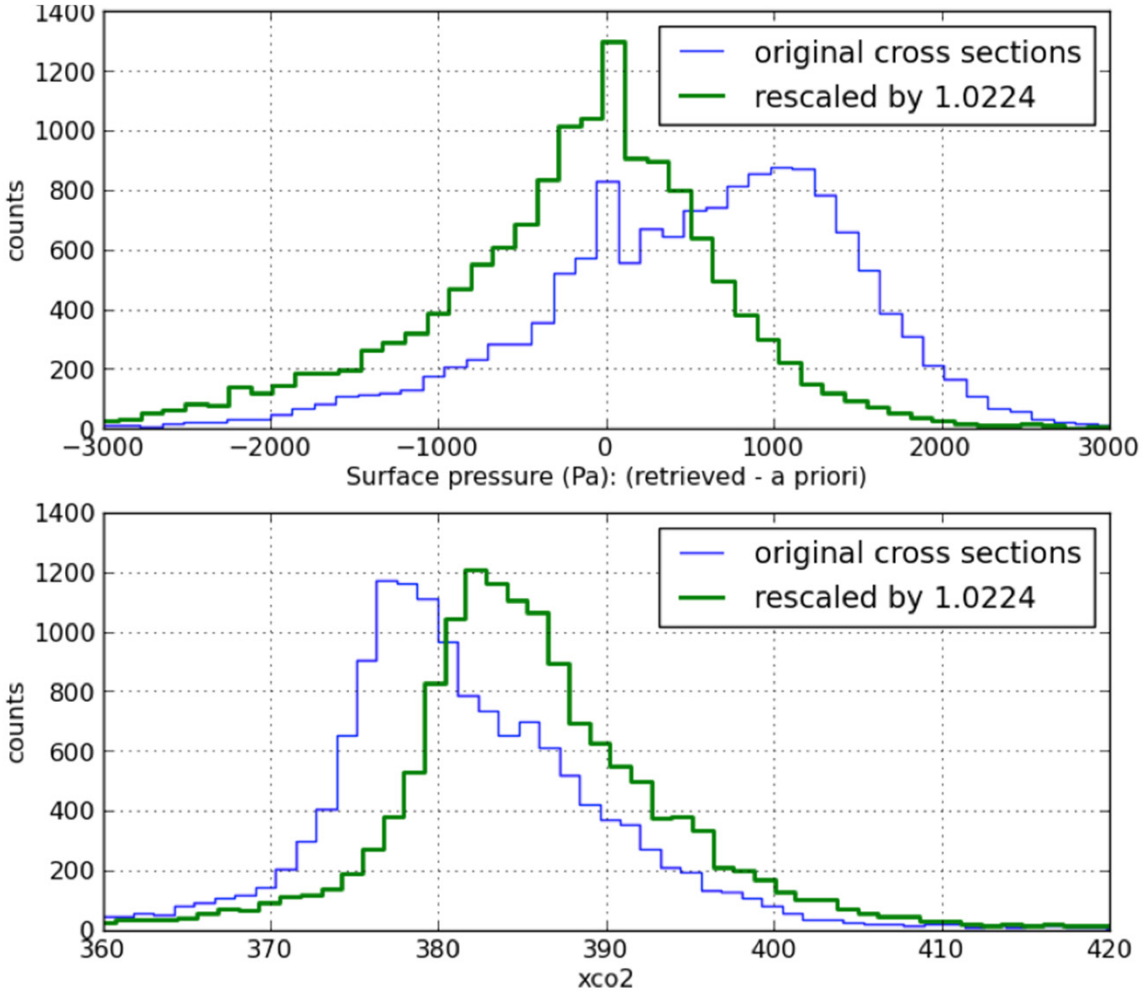


Wunch et al.

- ACOS GOSAT retrievals show
  - A consistent global bias of ~2% (8 ppm) in X_{CO2} when compared with TCCON and aircraft measurements.
  - X_{CO2} variations that are a factor of 2 to 3 larger than that measured by TCCON.

Biases in the X_{CO2} Maps

- About half of the 2% X_{CO2} bias is associated with a ~10 hPa high bias in surface pressure
- The O_2 bias be due to:
  - Uncertainties in the O_2 A-band absorption cross sections
  - Radiometric and spectroscopic calibration errors in the L1B data
  - Errors or oversimplifications in the retrieval algorithm

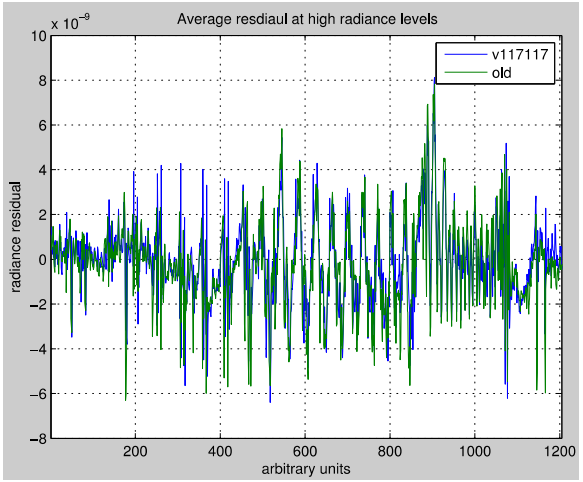


Rescaling the O_2 A-band absorption cross sections reduces the global XCO2 bias to by half

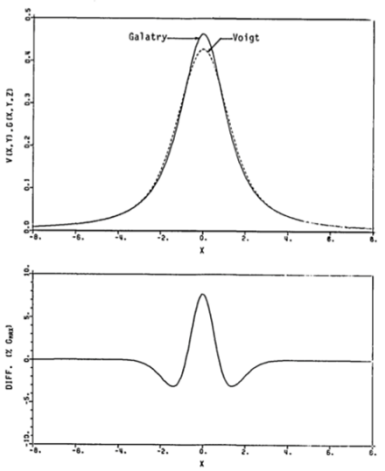
Improvements in Spectroscopy

- To address the known biases in the O_2 A-band and near IR CO_2 bands, the ACOS team is working closely with the spectroscopic measurement and modeling communities.

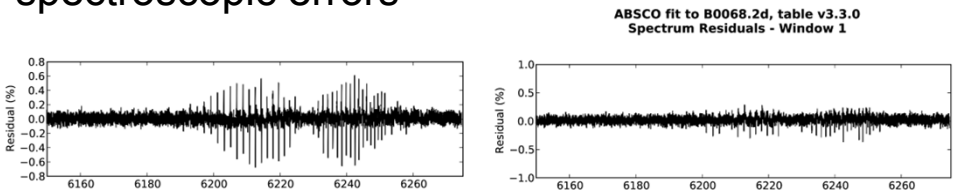
- A multi-spectrum fitting approach is being used to derive new line parameters using a self-consistent treatment of:
  - Line mixing
  - Non-Voigt line shapes
  - Dimers/quasi-bound dimers
  - Pressure-induced absorption
- Preliminary results for the weak CO2 band are showing promise



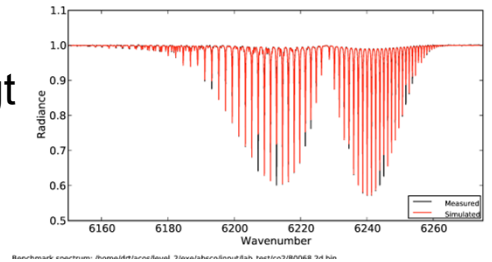
Characteristic structures in O_2 A-band provide evidence for spectroscopic errors



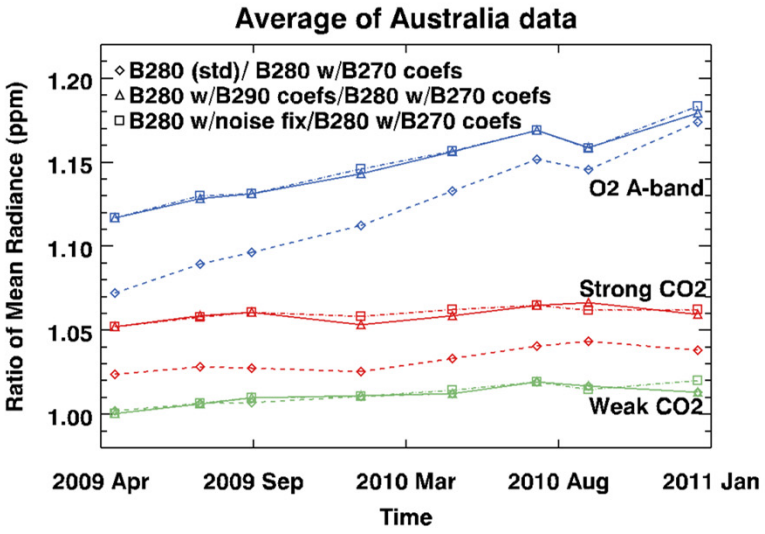
Galatry vs Voigt Line shape



Change from Voigt to Speed-Dependent Voigt line shapes have substantially reduced residuals.

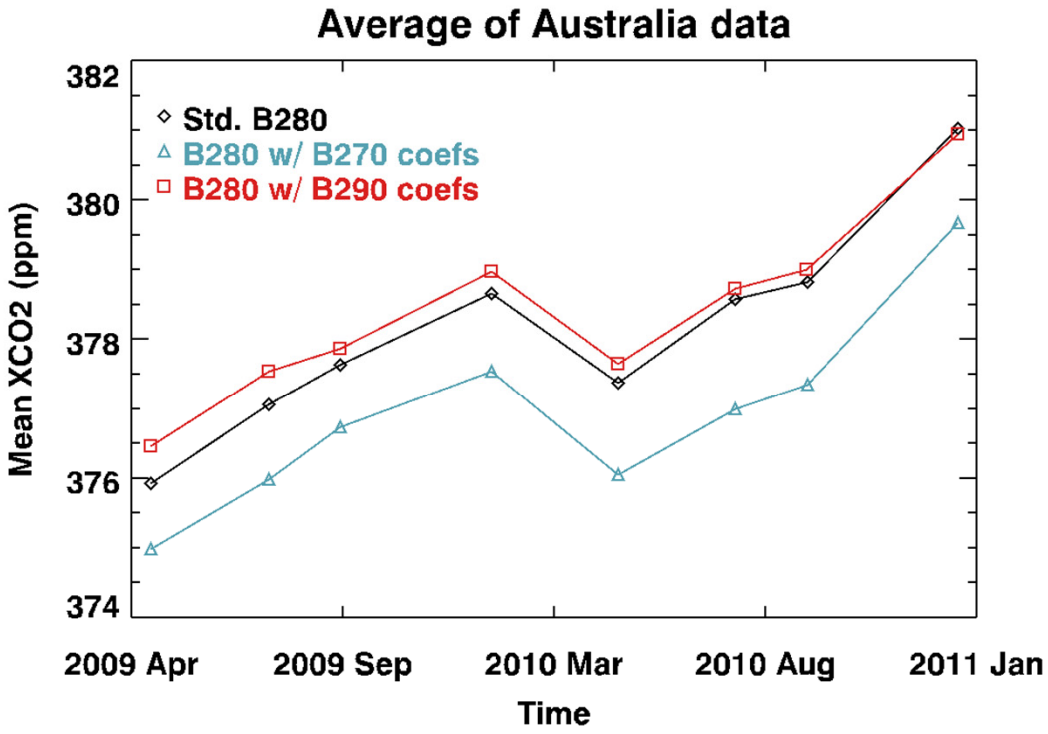


Impact of Radiometric Errors



- If not corrected, these radiometric errors contribute a ~1.5 ppm (0.3%) error in the X_{CO2} retrievals
- The current ACOS XCO2 product delivery (B2.8) uses early estimates of this correction
- A more accurate correciton will be included in the next version of the ACOS product (B2.9)

The throughput degradation discovered in the Railroad Valley vicarious calibration tests was not accurately incorporated in initial ACOS data releases

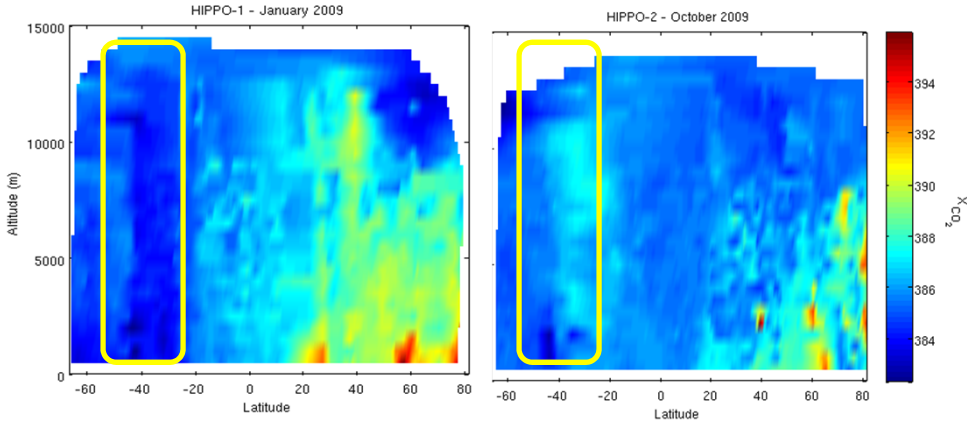


Other Products of the ACOS Validation Program

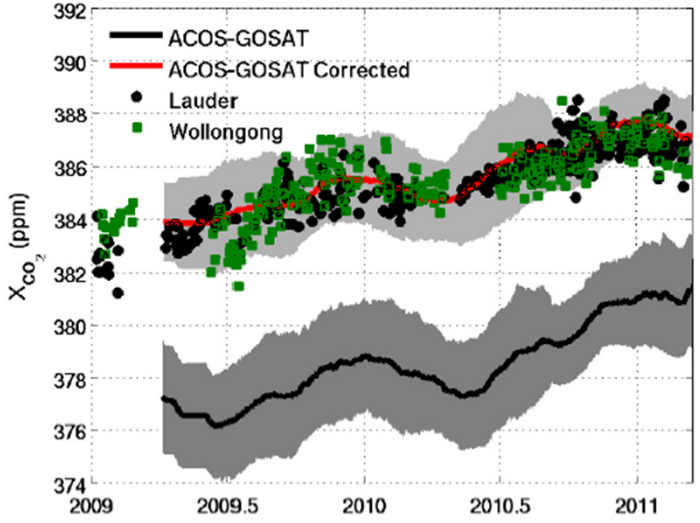
- ACOS XCO2 products retrieved over the southern hemisphere, which has little known variability, have been assessed to identify other sources of bias
- Wunch et al. have identified biases associated with:
  - Difference between ABO2 and SCO2 albedos
  - Surface pressure difference

    $dP=P_{ret}-P_{ECMWF}$
  - Air mass
  - A-band Signal Level
- A multivariate formula has been developed to correct these biases

See Wunch et al. (Session 2).



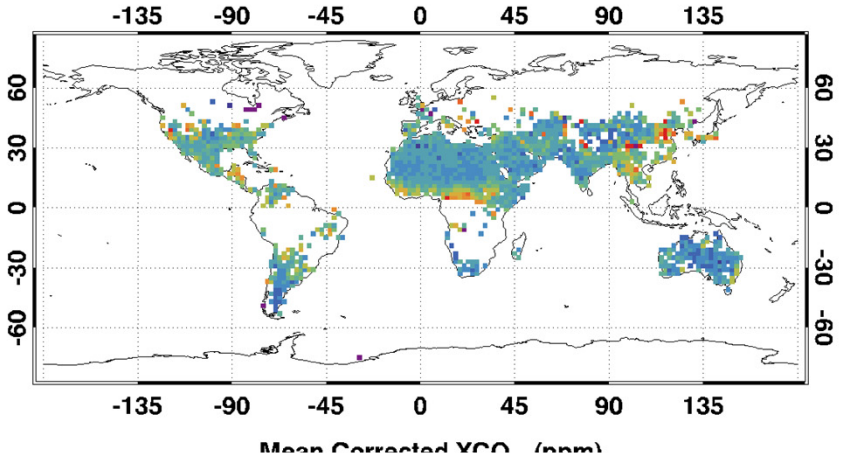
HIPPO-1 and HIPPO-2 show little CO2 variability over the Southern Hemisphere.



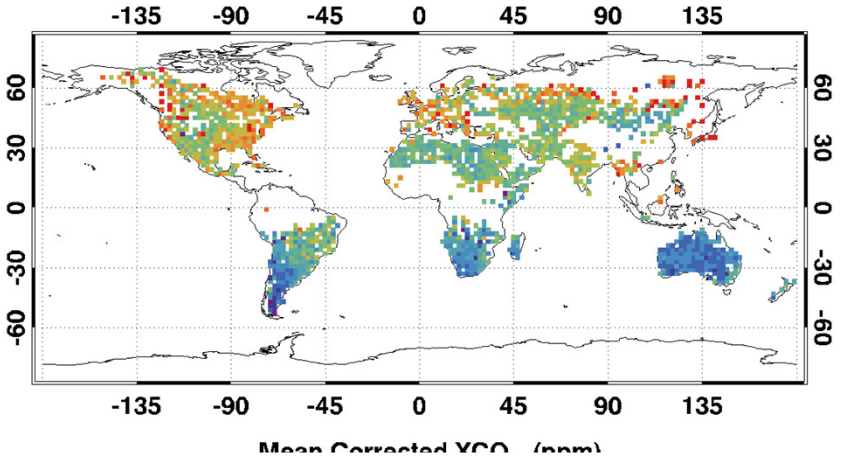
The corrections substantially improve the fits over SH TCCON sites

Corrected Global Maps of X_{CO2}

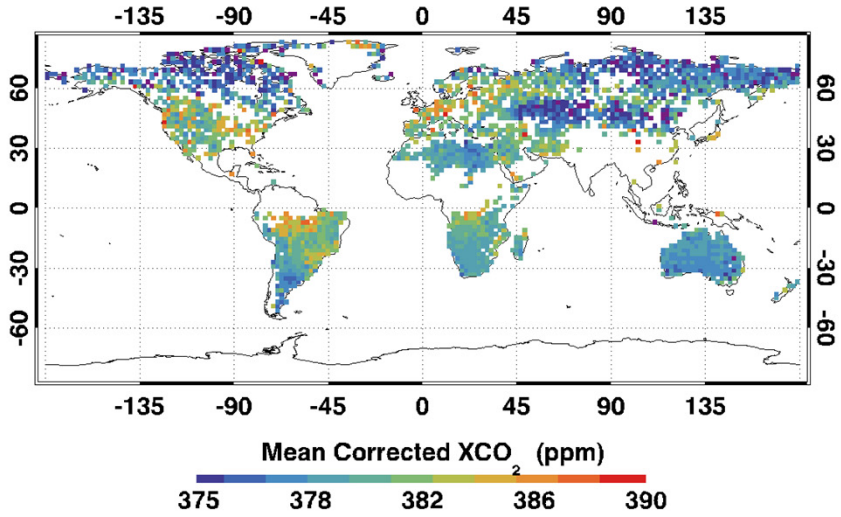
2010-01-01 -- 2010-01-31 Land



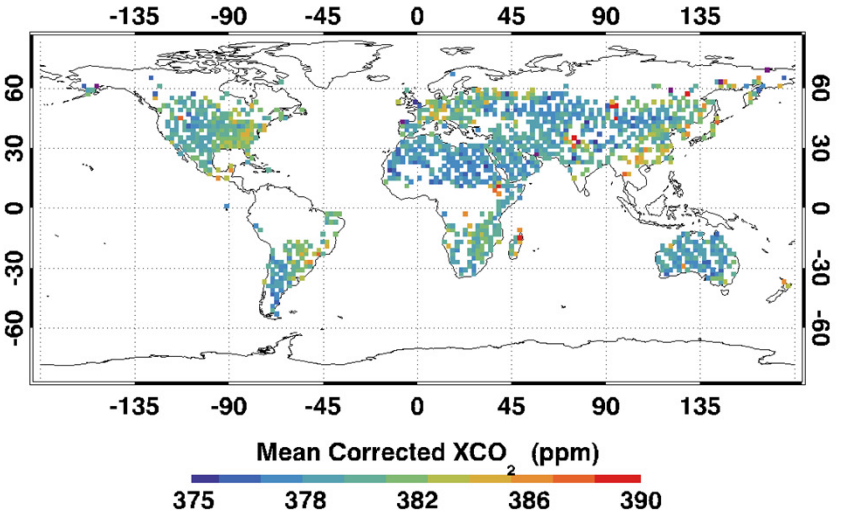
2010-04-01 -- 2010-04-30 Land



2010-06-30 -- 2010-07-31 Land

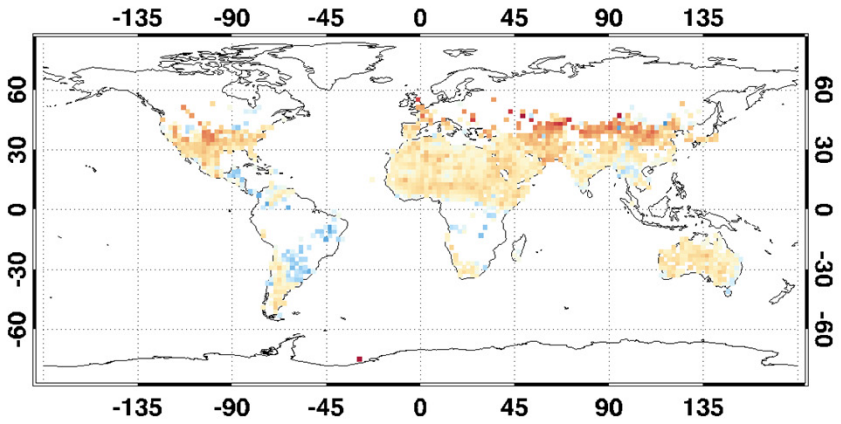


2010-10-01 -- 2010-10-31 Land

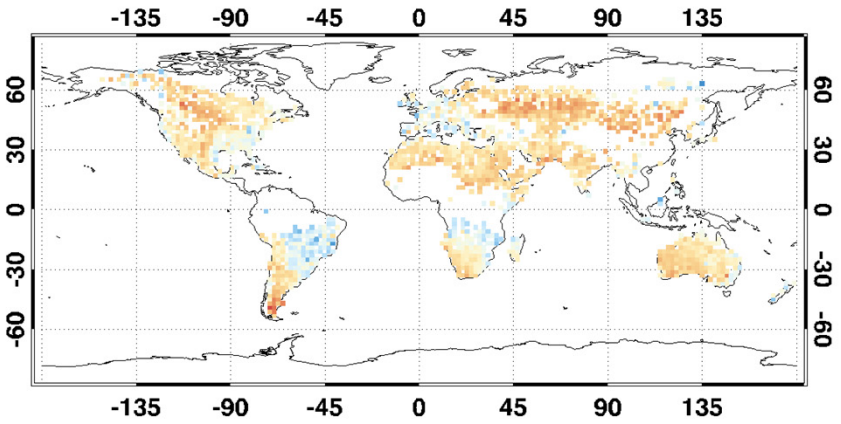


Impact of Know Biases on Retrieved Global X_{CO2} Distribution

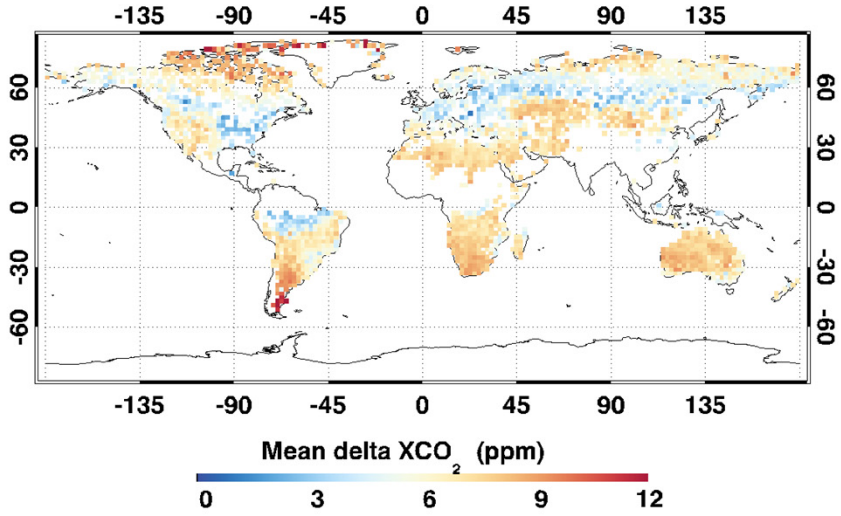
2010-01-01 -- 2010-01-31 Land Delta XCO2 (multi parameter)



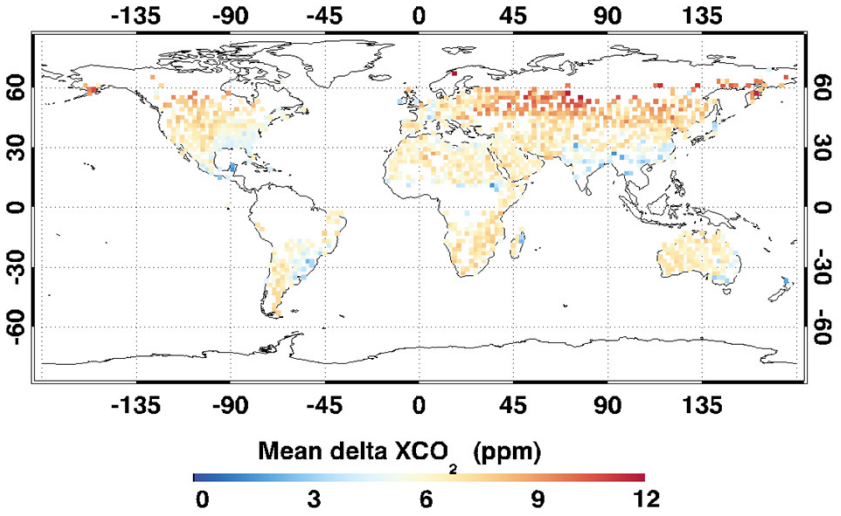
2010-04-01 -- 2010-04-30 Land Delta XCO2 (multi parameter)



2010-06-30 -- 2010-07-31 Land Delta XCO2 (multi parameter)



2010-10-01 -- 2010-10-31 Land Delta XCO2 (multi parameter)



Conclusions

- The ACOS/GOSAT collaboration is beginning to return benefits to both teams
  - The OCO-2/ACOS retrieval algorithm is:
    - currently in place and is generating a production product for GOSAT
    - still evolving, to address know errors and biases
  - The vicarious calibration experiments have helped to identify and correct for changes in the pre-launch GOSAT radiometric calibration parameters.
  - Comparisons with TCCON measurements have revealed a global, -2% bias in the preliminary ACOS X_{CO2} retrievals
    - About half of this bias can be attributed to a +10 hPa bias in the retrieved surface pressure (and air mass)
- Lessons learned from this experience are expected to substantially accelerate the delivery of high quality products from the OCO-2 mission **(see talk by Eldering et al. in Session 5)**